SOURCES OF IONIZING EXPOSURE TO THE GENERAL PUBLIC*

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IN the first 40 years of this century, prior to the wartime development of the atomic energy industry, about two pounds of radioactive material were taken out of the earth's crust in the form of radium. That, plus a moderate amount of thorium and uranium, was the total quantity of radioactive material available to produce injury. And those two pounds of radium killed over a hundred people!

Then came the war, with the artificial manufacture of literally thousands and thousands of tons of the radioactive equivalent of radium. In the last twenty years, since fission was first conducted on a large scale in Chicago, these millions of curies of radioactivity have resulted in a half-dozen deaths up to the present time, and all six deaths were due to accidental causes.

This emphasizes the tremendous contrast of the pre-war and post-war experience. Radiation injuries of a recognizable sort are so rare that, in this city for example, I can remember only perhaps a half-dozen in the 26 years that I have been interested in this subject. Most of the injuries have been due to x-ray exposure. Known cases of radiation injury are indeed rare. In fact, they are much less frequent now than before the war, despite the much more widespread use of radioactive materials.

In contrast to readily identifiable injuries to individuals having had known exposure to ionizing radiation, we must also be concerned about the possibility of radiation-produced genetic injury, leukemia, and other neoplasms whose frequency cannot be measured readily in the population, but can only be estimated on a statistical basis. This is because the *noise level* in the general population is so high that we have no hopes at the present levels of exposure of detecting the *signal*. In other words, the additional numbers of cases due to exposure to ionizing radiation are too

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few to be observed.

Why is the noise level so high? Well, let us start with natural radioactivity. In this city, we are exposed to almost 100 millirads per year. This is divided roughly into about 40 millirads from internal sources and about 60 from external sources. The internal component comes from potassium-40, carbon-14 or radium.

The actual levels of exposure due to natural radioactivity are quite variable. If we compare the levels in parts of Brooklyn to those in Washington Heights, we find there is about 20 per cent difference. This is because large areas of Brooklyn are on sand which is relatively low in natural radioactivity, whereas Washington Heights is on Manhattan schist which is higher in radioactivity. Washington Heights is also 200 or 300 feet higher in altitude, and a person living there receives a few millirads per year additional exposure to cosmic rays. Thus, even in New York City there is about a 20 per cent difference depending on where one lives. In addition, if one lives in a wooden house, he receives more cosmic ray exposure than if he lived in a brick house. On the other hand, if he lives in a brick house, the brick may contain radium, and this may increase his exposure.

As we go to other parts of the world, for example, in parts of India and Brazil, people are exposed to as much as 10 or 100 times the radiation levels present here in New York

Having considered natural sources of exposure, we can now turn to the medical uses of ionizing radiation. This is an important and valuable application that has developed steadily. In New York City, and based on studies in hospitals, Loughlin and Pullman estimated that the per capita dose from the diagnostic use of x-rays was about 100 millirads per year in 1956. Based on evidence that is now developing, the per capita dose may be higher by an as yet unknown factor. Most of the studies that have been conducted up to the present time have been in large institutions, where it is fairly easy to control the relatively few machines with which great numbers of people are radiated. A study is now being made of the doses received in private offices of the thousands of physicians in New York City that use x-ray units. We are finding frequent deviations from good practice that could result in the original estimate of per capita dose being increased considerably. However, in round figures, we can say that natural radioactivity and medical x-rays each deliver a per capita dose of about 100 millirads per year.

Occupational exposure, as far as the public is concerned, is so small that one cannot really estimate it—it is insignificant. There are individuals who are receiving considerable doses, but the occupational exposure approaches zero millirads per year when one dilutes their exposure in the population as a whole. In considering population effects at low doses, it is permissible to speak of averages.

Fallout is a fourth component of the population dose. The dose to the skeleton or gonads averages 5 to 10 millirads per year, and the iodine-131 dose to the thyroid will be somewhat higher. The 1961 Soviet tests resulted in a period of thyroid exposure from iodine-131, which lasted from about the first of October until the middle of December. We estimate that the milk-drinking components of the population received about 50 millirads of exposure to the thyroid from iodine-131.

In summary, the general population is subject to three measurable sources of exposure: natural radioactivity, medical x-rays and fallout. The latter contributes about 5 per cent of the total dose to the gonads and skeleton, and a higher fraction of the total dose to the thyroid.

Of the total dose to which the public is exposed, the part that we can do the most about is the medical component. I am certain that Hanson Blatz, who is here tonight, would agree that if the equipment now available were used properly and if the use of the equipment were limited in the ways which the radiologists themselves have agreed it should be, the per capita dose from x-ray could be reduced substantially. This is really the only large component of exposure which we can reduce. We certainly cannot do much about natural radioactivity, and the dose from weapons testing is so small that if it were eliminated entirely the total would not be greatly affected.

Up to now I have been speaking entirely about population exposures, in the sense that we are considering effects that can only be estimated statistically. However, I should point out that within the groups that have been medically exposed are isolated populations that should be of very great interest, because many of them have received doses sufficiently high to enable us to detect somatic changes even in the relatively small groups. For example, Dr. Albert is presently studying more than two thousand children who received a very high dose in the course of radiation treatment for tinea capitis. The dose to the scalp was about 400 roentgens, with 100 KV x-rays, which represents a substantial whole-body and thyroid dose.

To summarize, the occupational component of exposure is minimal for the present time. The largest component in which we can make improvement is the medical component, which is probably about equal in magnitude to the natural radioactivity. With regard to the future, I shall close with just one brief comment. I do not think that the waste disposal problem is of importance in public health at the present time: it is a problem in economics, and the Atomic Energy Commission cannot develop a nuclear energy industry until the economics of waste disposal is solved. But the procedures that can be used, and are being used, are certainly adequate for the time being, and probably for the rest of this century. But if we extrapolate beyond the year 2000, with the present forecasts of the rate at which nuclear energy will be incorporated into the power industry, we find that about 10^{12} curies of strontium-90 will exist in the world in the year 2000. Now to put that in perspective, the total amount of strontium-90 that has been produced by weapons tests up to the present time is about 10^{7} curies, which means that in the year 2000 there will be 100,000 times more strontium-90 in the world from power reactors.

Let us suppose that 1 per cent of this 10^{12} gets out of hand. There will then be 10^{10} curies of radioactivity in the environment, which would be a thousand times more than we have now from weapons fallout.

MODERATOR CHADWICK: Next, we would like to ask Dr. Harley to comment on ingestion of food stuffs contaminated with radioactive material. Dr. Harley!